Properly run and interpreted, cement-bond logs (CBL) provide highly reliable estimates of well integrity and zone isolation.

by

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Casedhole Solutions

Presented to the

GEOLOGY & WELL TECHNOLOGY SECTION FALL 2015 WELL LOGGING WORKSHOP September 2, 2015



Examples in this presentation are courtesy of Halliburton, Schlumberger, Baker Atlas, NCPS, FMC and many other witty forunners of this methodology.



Purpose of Cement

- Cement is used for:
 - structural support to the casing to reduce the risk of a casing failure
 - providing hydraulic & gas isolation
 - preventing production of unwanted formation fluids
 - isolating intervals to ground water (ERCB)
 - providing structural strength and isolation during fracturing

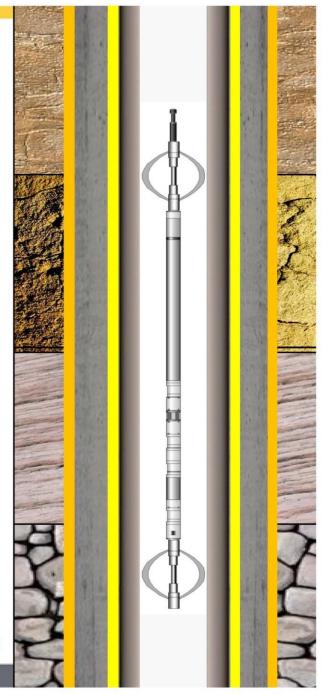






Reasons for Bond Log

- Bond logs are run to determine:
 - Cement to casing relationship
 - Cement to formation relationship
 - Evaluate cement conditions:
 - Channeling
 - Compromised cement (i.e. gas cut, dehydrated, etc.)
 - Cement stages
 - Cement top
 - Microannulus

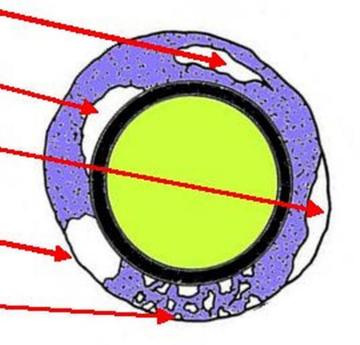






Scenarios to keep in mind for bond log evaluation:

- Channeled cement
- Poor bond to pipe but good bond to formation?
- Good bond to pipe and poor bond to formation
- Poor bond to both pipe and formation
- Compromised cement (i.e. gas cut cement)

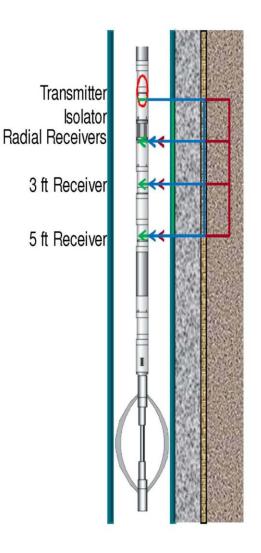




What is Measured on Bond Logs

- Recorded on ALL sensors:
 - Amplitude (strength of the first arrival)
 - Travel Time (time it takes for the signal to go from transmitter to receiver)
 - VDL Variable Density Log

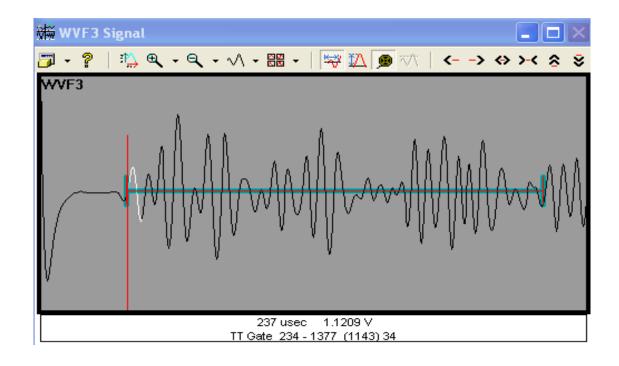
 (entire waveform from 1st
 arrival and reverberations up
 to 1200 μs...from one pulse)







Theory of Measurement

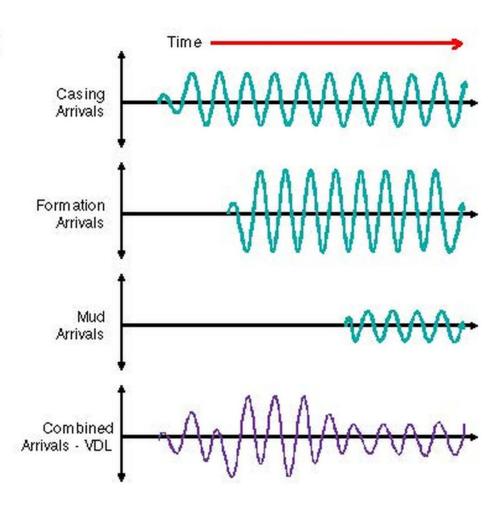


- Measures Sound Wave Amplitude (m-volts)
- Measures Sound Wave Transit times (usec)



VDL Variable Density Log

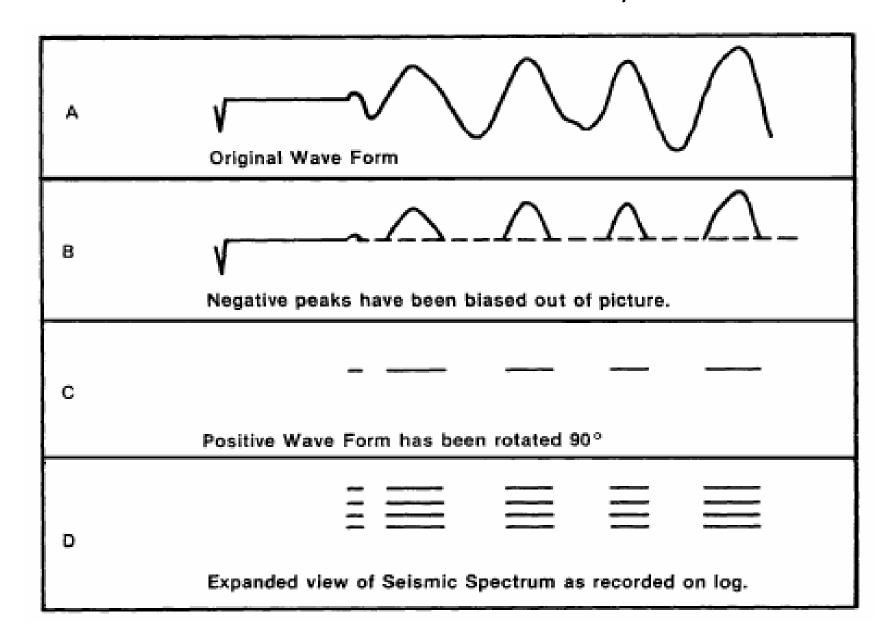
- After the transmitter fires, the waveform arrives at the sensors via different paths:
 - Casing
 - Formation
 - Mud
- Arrival times are a function of:
 - Distance traveled
 - Slowness of medium (~density)
- The waveform recorded at each sensor is a combination of all arrivals present





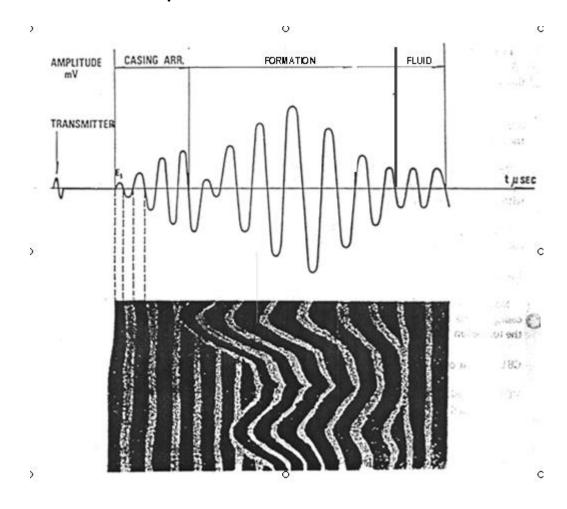


VDL – Variable Density

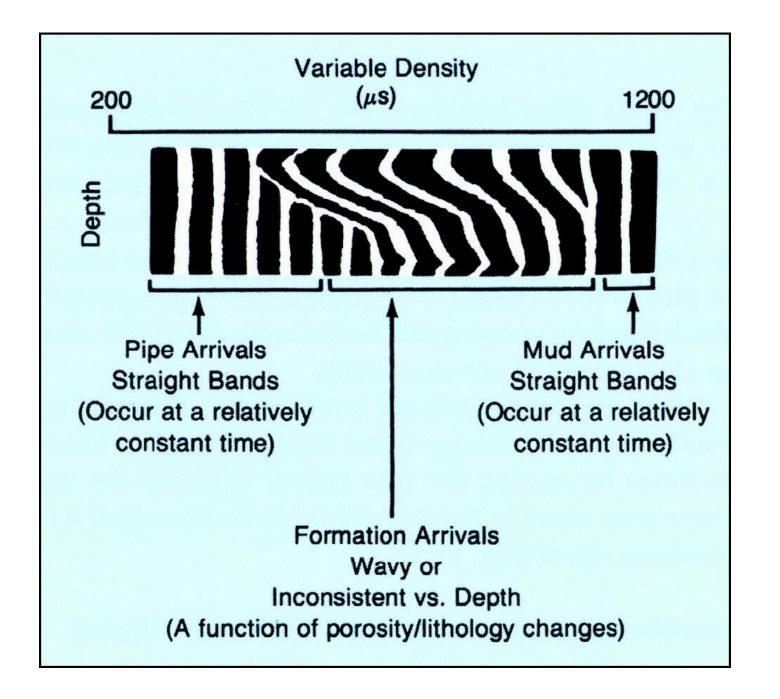




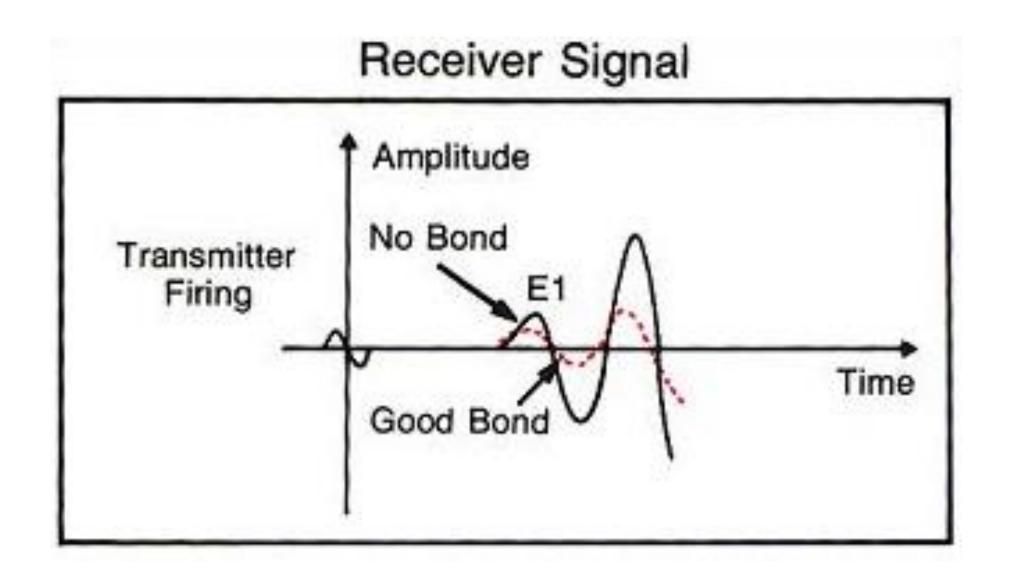
Cement to Pipe Bond & Formation VDL







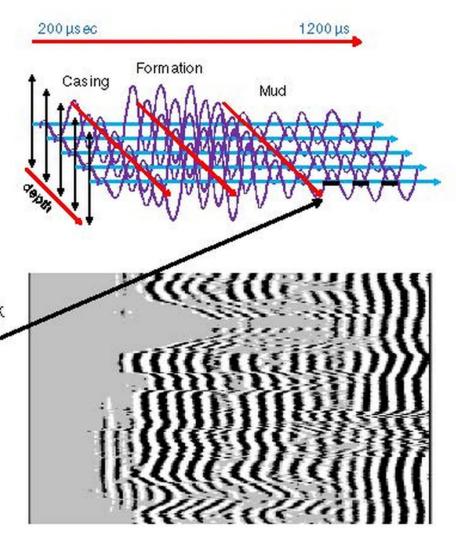






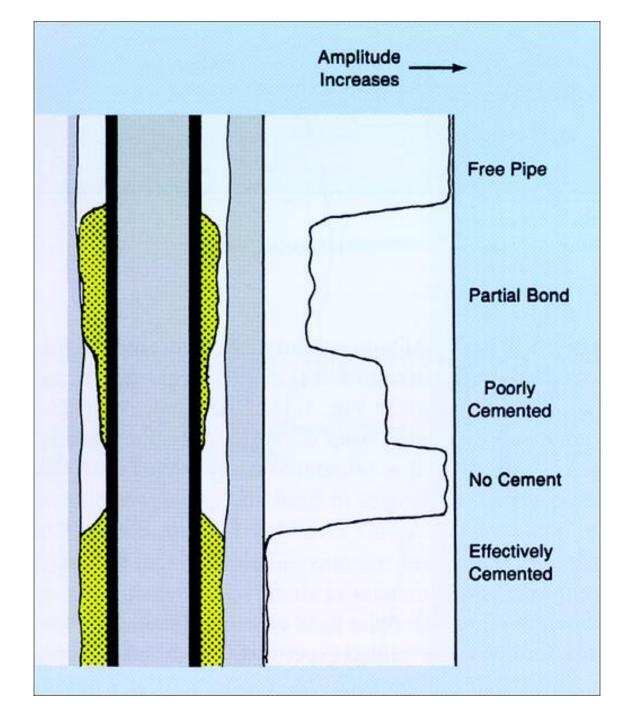
VDL Variable Density Log

- VDL displays multiple "slices of data" side by side
 - 200 1200 μs for 3' VDL
- Arrival patterns start to become apparent
- To make a 2D picture of the 3D image:
 - Positive peaks are shaded black
 - Negative peaks are shaded _
 white
- Casing arrivals should be consistent but formation arrivals "should" change with lithology



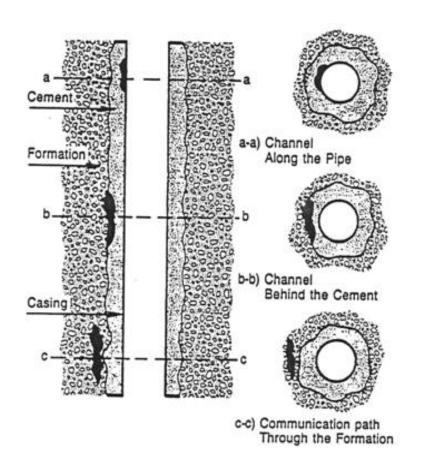


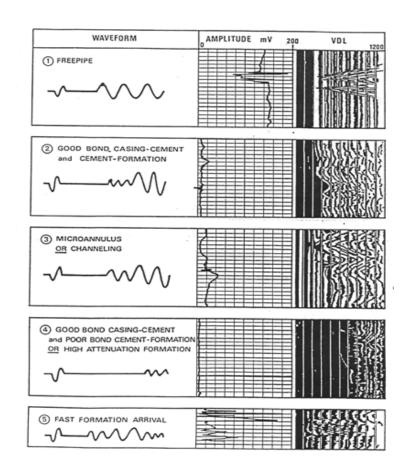




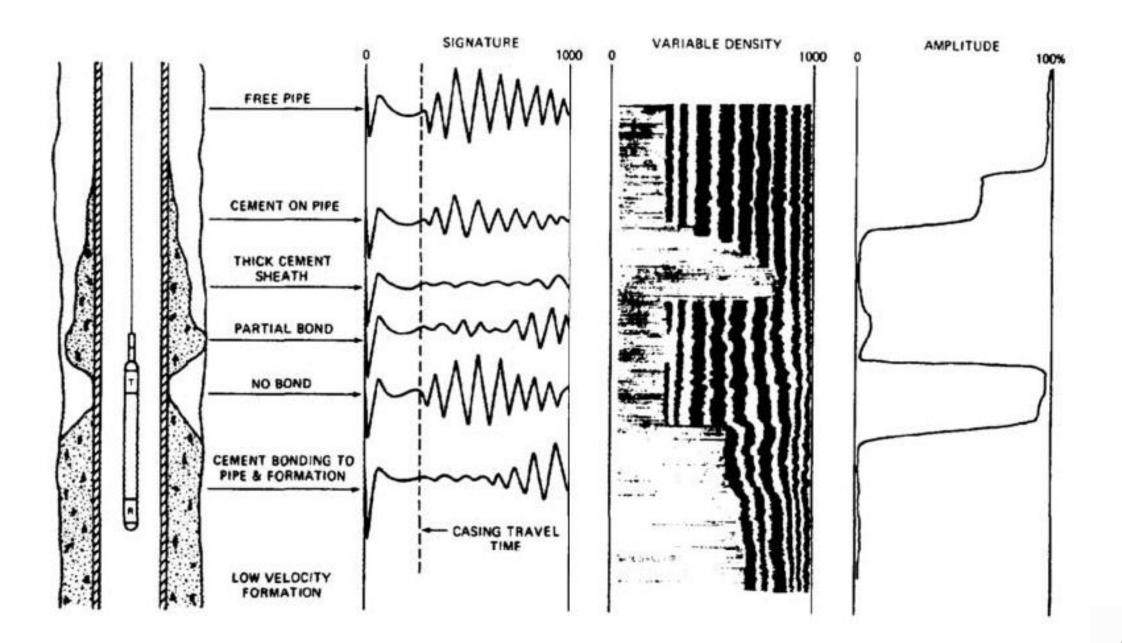


Cement Quality 1



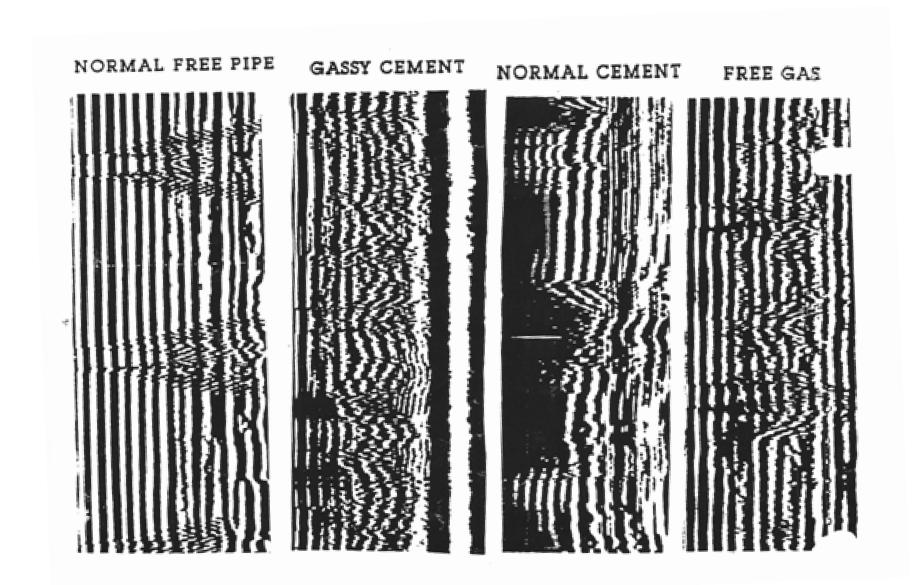








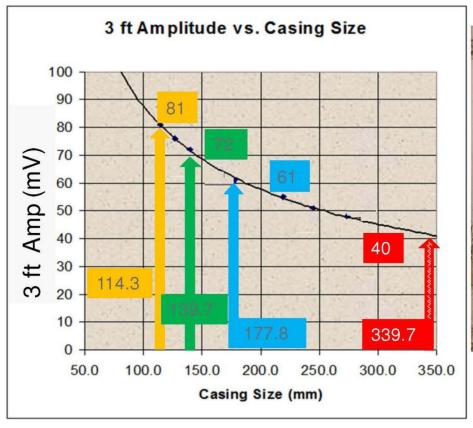
Cement Quality 2





Amplitude Signals vs. Pipe Size of "free" pipe

* immersed in water





Challenge is as casing sizes get larger, the range of measurement from no cement to fully cemented gets smaller.





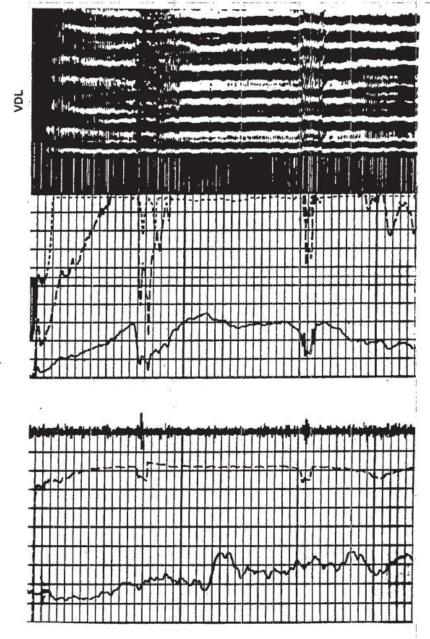
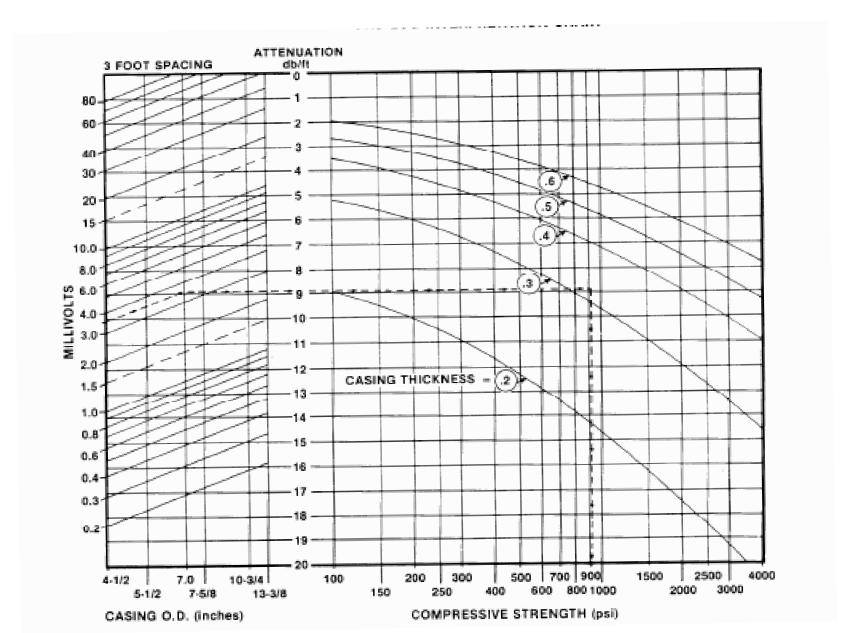


Figure 9. Tool not centered.



Cement Compressive Strength





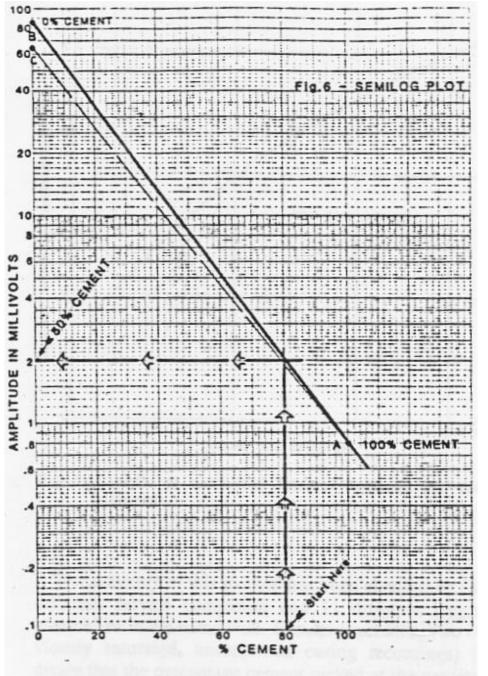


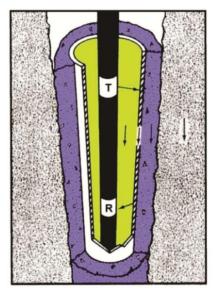
Fig. 6-Semilog plot.



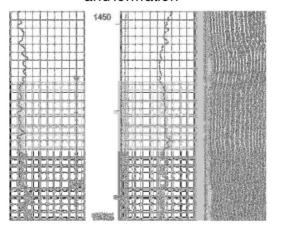
CASING SIZE	WT.	TRAVEL TIME u-SEC	FREE PIPE SIGNAL	—CLASS H 3000 PSI 60 100% CEME	
4-1/2	~9.5			0.2 mv	2.3 mv
	11.6	254	81 mv	0.6 mv	4.6 mv 5 Feet
	13.5			1.0 mv	7.0 mv
5"	15.0			0.9 mv	5.5 mv
	18.0	258	76 mv	2.2 mv	10.0 mv 5Feet
	21.0			3.6 mv	15.0 mv
5-1/2"	15.5			0.7 mv	4.8 mv
	17.0	269	72 mv	1.0 mv	6.0 mv 6 Feet
	20.0			2.1 mv	9.0 mv
	23.0			3.5 mv	13.0 mV
7"	23.0			1.0 mv	5.5 mv
	26.0			1.7 mv	7.5 mv
	29.0			2.4 mv	9.3 mv
	32.0	289	62 mv	3.3 mv	13.0 mv ll Feet
	35.0			4.0 mv	14.0 mv
	38.0			5.0 mv	15.0 mV
	40.0			6.0 mv	17.0 mv
7-5/8	~26.4			1.1 mv	5.5 mv
	29.7	302	59 mv	1.8 mv	7.5 mv 12 Feet
	33.7			2.6 mv	10.0 mv
	39.0			3.5 mv	13.0 mV
9-5/8"	40.0			1.8 mv	6.8 mv
	43.5			2.2 mv	8.5 mV
	47.0	332	51 mv	2.7 mv	9.0 mv 15 Feet
	53.5			4.0 mv	12.0 mv
10-3/4"	40.5			1.2 mv	5.1 mv
	45.5			1.8 mV	6.5 mv
	48.0			2.1 mV	7.6 mv
	51.0	352	48 mV	2.5 mV	8.0 mv 18 Feet
	54.0			2.7 mv	8.4 mv
	55.5			2.8 mv	8.8 mv



VDL Example Summary

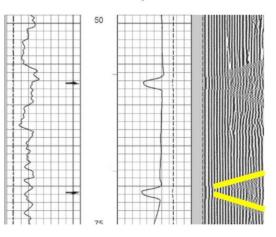


Good bond to both pipe and formation



T

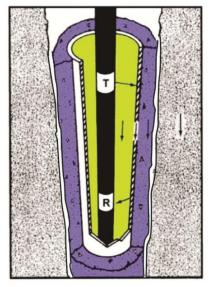
Free Pipe



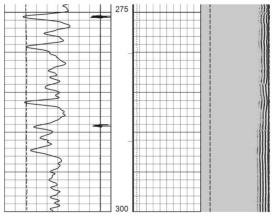




VDL Example Summary



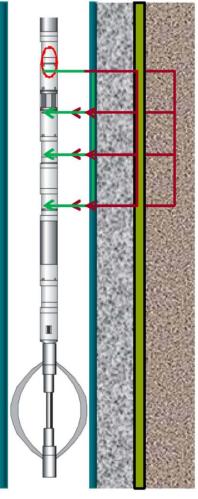
Good bond to pipe but poor bond to formation



Transmitter Isolator Radial Receivers

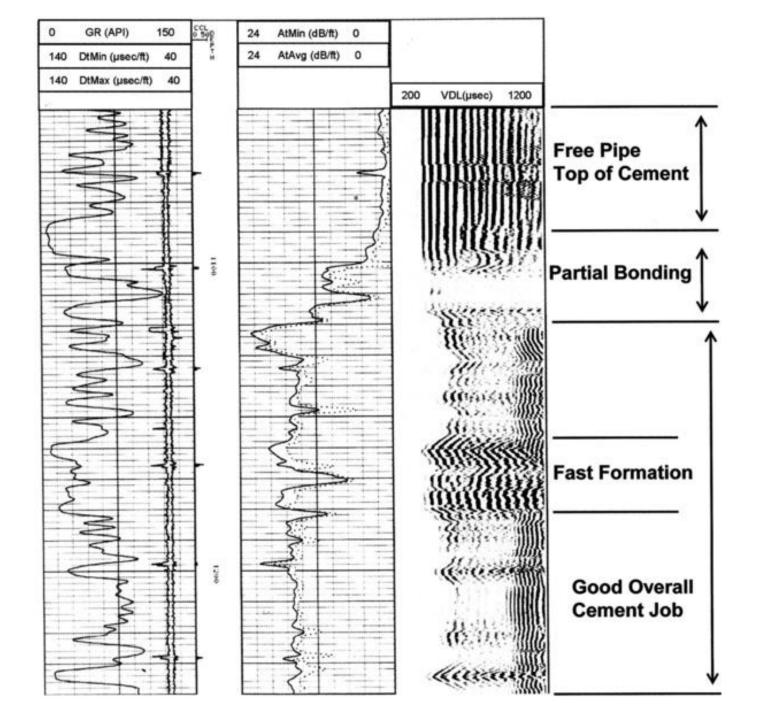
3 ft Receiver

5 ft Receiver

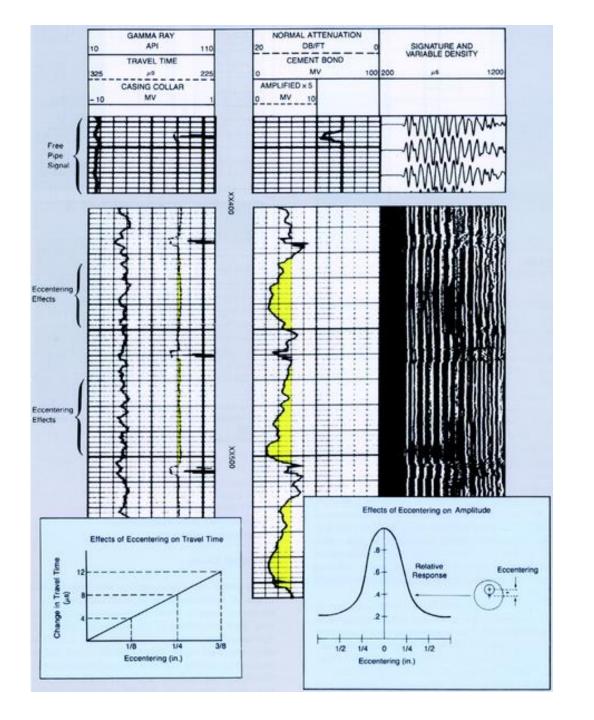






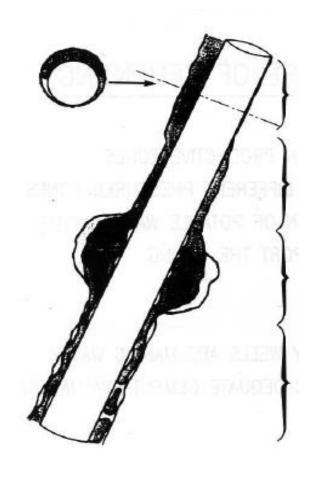








Quality Control CBL – Cementing & Drilling

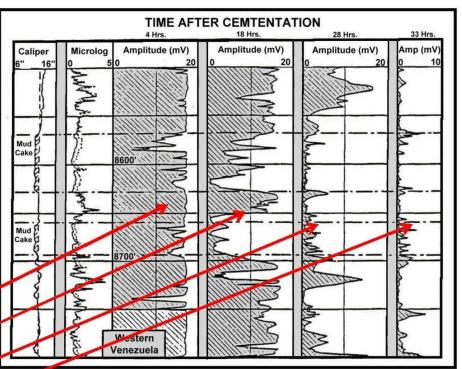


- Poor Centralization
- Cement Shrinkage or Micro-annulus
- Drilling fluids
- Cement density
- Deviated Wells
- Cement setting time.
- Inefficient Pre-flush



Amplitude changes caused by Compressive Strength vs. Time

- Green cement
 - Low compressive strength hence higher than normal amplitudes
 - Rule of thumb is to not run bond logs up to 48 hours after cementing (cement types such as thermal cements may vary)
- Chart shows the reduction in amplitude with time after cementing
 - 4 hours
 - 18 hours
 - 28 hours
 - 33 hours



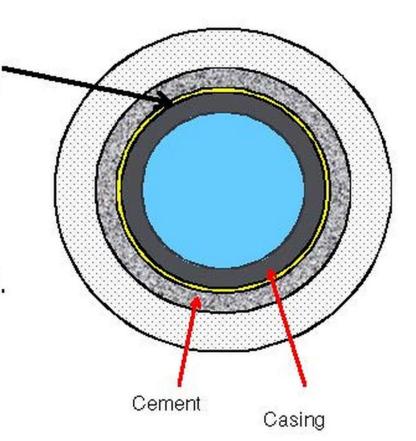




Micro-annulus

 Micro-separation (yellow) between pipe and cement (< 1 mm) caused by a drop in temperature or pressure

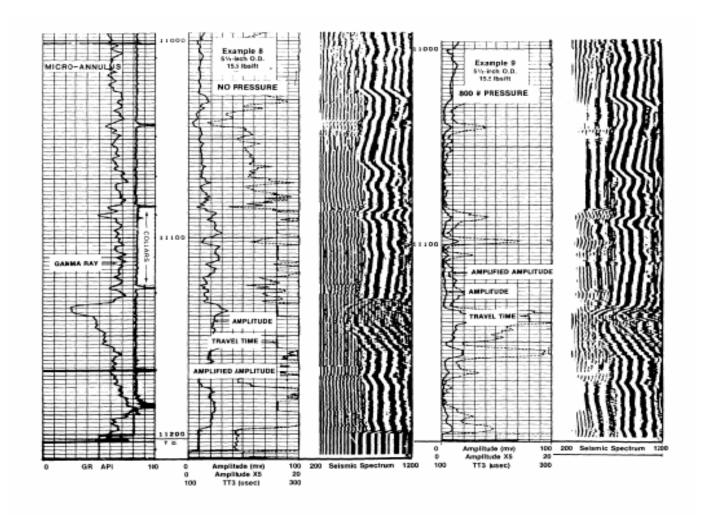
 Identified by doing a "pressure pass" to a "nonpressure pass" comparison.







Micro Annulus – Pressure Logging

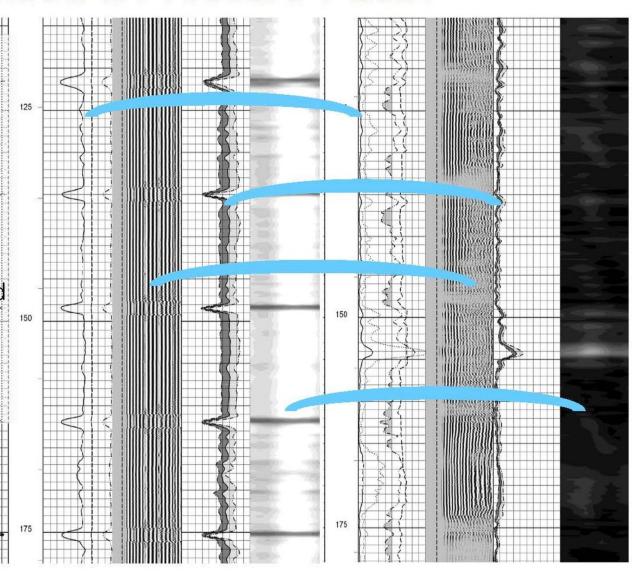




Do I need a Pressure Pass?

Micro-annulus Example

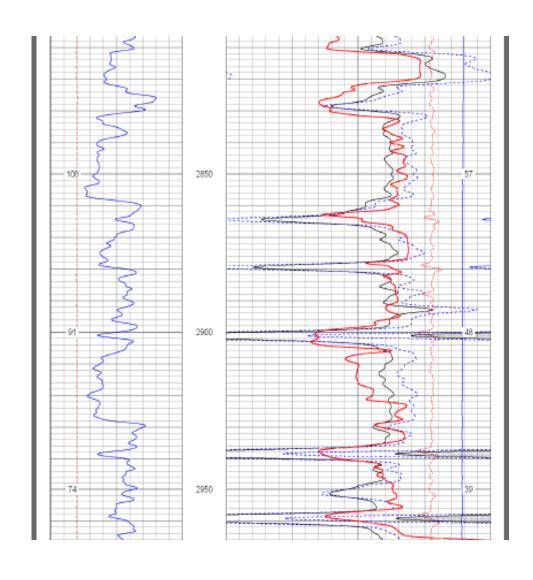
- Non-pressure pass looks like mostly free pipe
- Pressure pass indicates strong micro-annulus due to decreased amplitudes as seen on radial map as well as reduced casing arrivals in VDL.







Open Hole Data –vs.- Travel Time Log

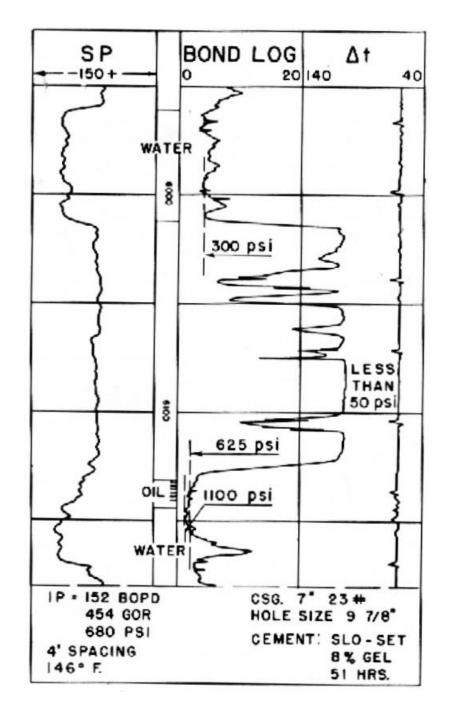


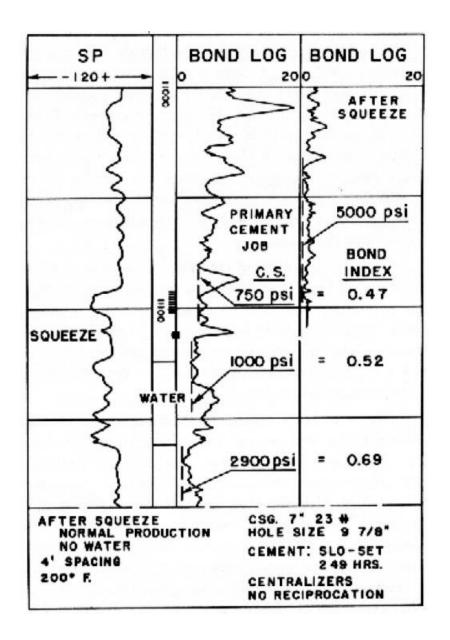
- Red TT3
- Blue Rhob

Coal Seams

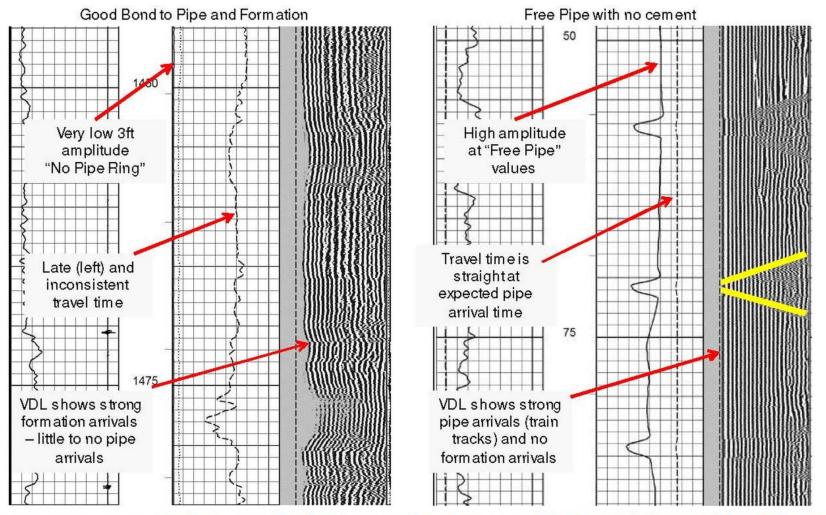
- Coal Seams
- Coal Seams







Amplitude, Travel Time & VDL – Example Extremes



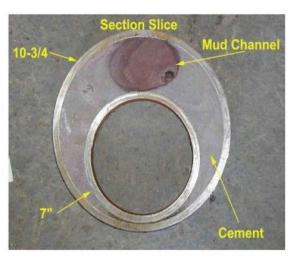
Note: L to R: standard Amplitude s caled 0-100 mV; standard Travel Time s caled 650-150 μsec, VDL scaled 200 – 1200 μsec



Bond log considerations of SCVF/GM

- Poor Primary Cementing/Hole conditioning
 - Mud Contaminated cement
 - Gas Cut Cement
 - · Channeled cement
- · Decentralized casing string
 - Vertical
 - Slant
 - Horizontal





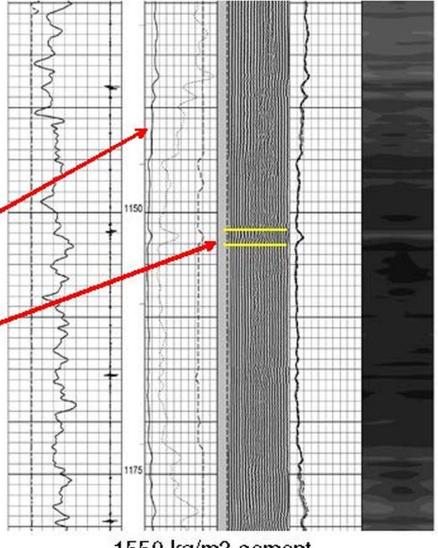






Well Conditions That Affect Bond Logs – Light Weight Cement

- Pipe is allowed to carry some pipe arrivals even under perfect bonded conditions
- 3ft amplitudes may range between
 5-10 mV (depending on density)
- Formation arrivals, if present, may have a faded appearance
- Collars DO NOT chevron but may exhibit a straight line response
- Cementing information from the well is critical for interpretation:
 - · Stages, Cement Density, Volumes

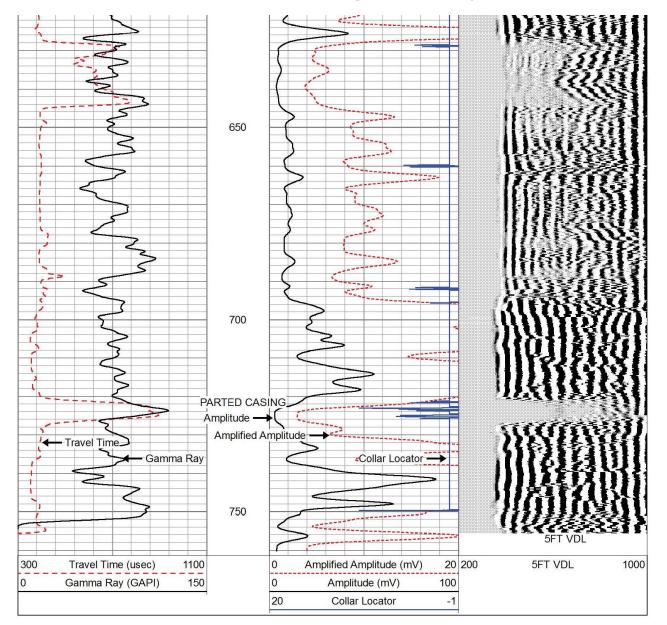


1550 kg/m3 cement

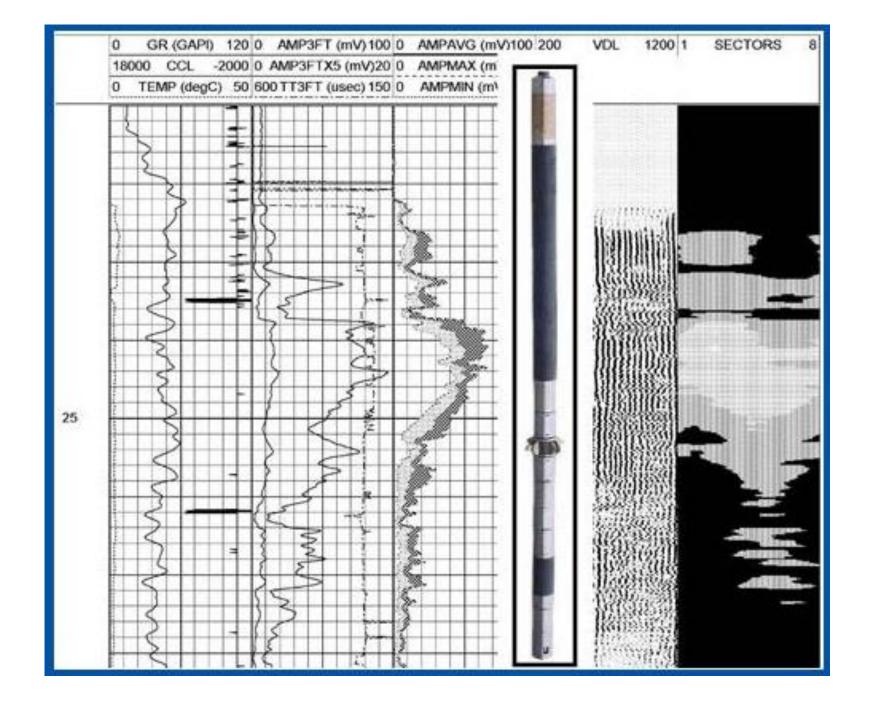




Parted Casing Example



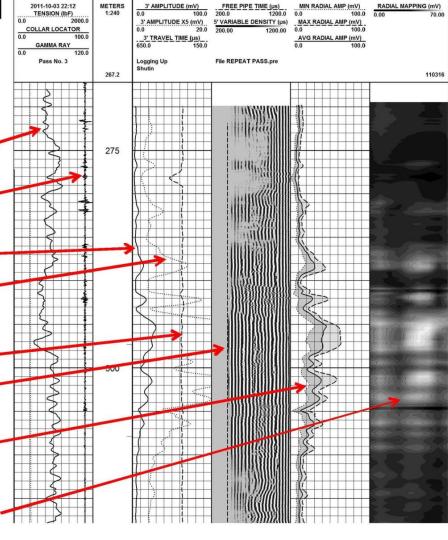






What is Measured & Presented on Radial Bond Logs

- Presented on the log:
 - Natural Gamma Ray
 - Casing Collar Locator
 - Amplitude from the 3ft
 - Amplitude x 5
 - Travel Time from the 3ft
 - VDL from the 5ft
 - Amplitudes from the eight / six radials (if RBL)
 - Min, Max and Average of the Radials (if RBL)

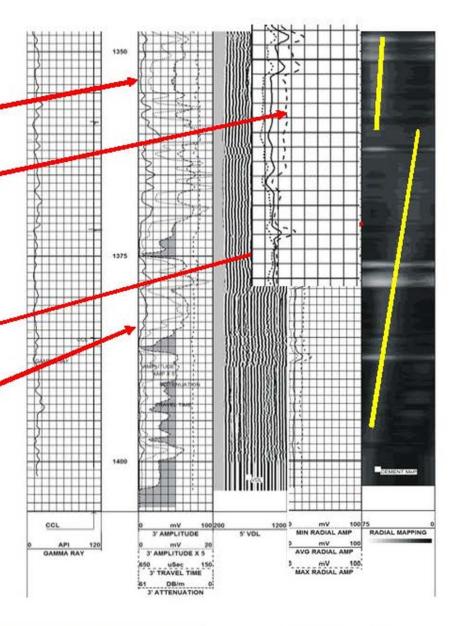






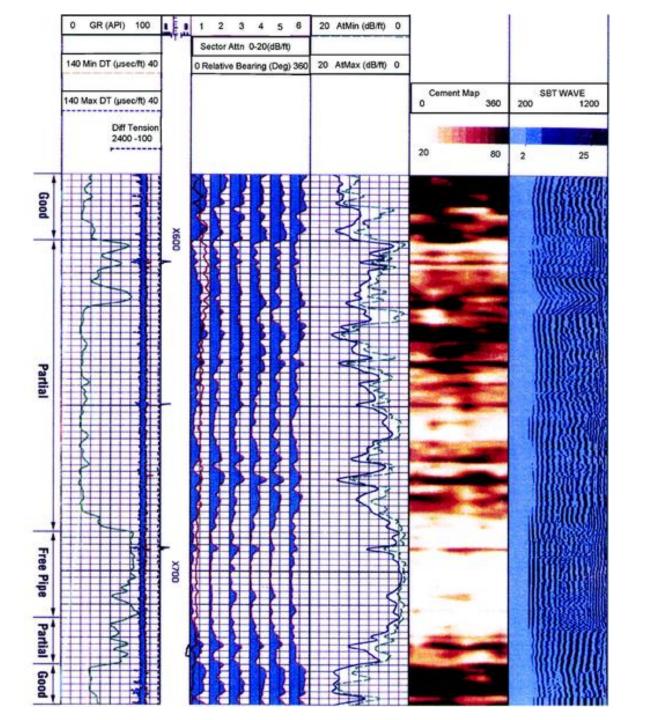
Channeling

- CBL outputs show overall good cement
- Radial outputs show inconsistency of several of the radial receivers
- Image mapping of 8 x 2' amplitudes shows channel of lower compressive cement
- Single CBL 3' amplitude can not identify channeling
- VDL is also inconclusive



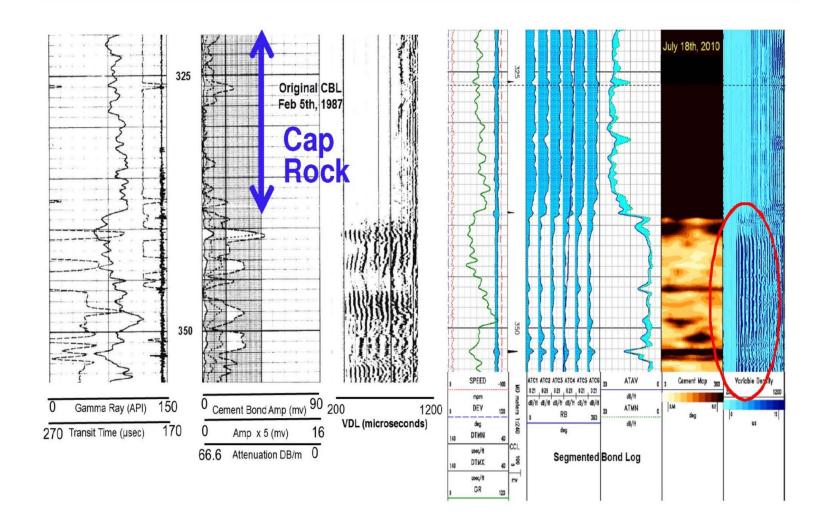






Log presentation for the Baker Atlas SBT tool containing individual log curves, cement map, and VDL display (courtesy of Baker Atlas)









EPA - Injection Well Mechanical Integrity

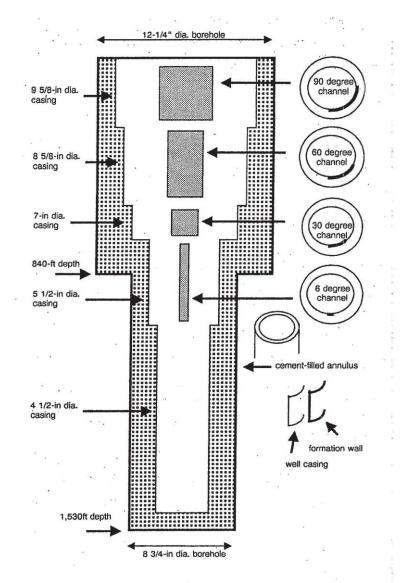


Figure 1. Logging Well No. 1.

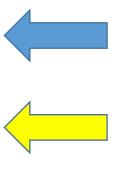
Logging Equipment

None of the logging tools presently available located any of the 6 degree channels in Logging Well No. 1. The second generation tools located all of the 30, 60 and 90 degree channels that were designed into and could be identified in the well. A calibrated single transmitter/dual eceiver cement bond tool with 3-foot/5-foot spacing located the 60 and 90 degree channels and all but one of the 30 degree channels. The other cement bond tools with single transmitter/single receiver 3-foot, 4-foot, or 5-foot spacing presented very inconsistent results.

The 3-foot spacing is the best currently available for measuring and evaluating the amplitude of the first compressional arrival and the attenuation of this signal is a measure of the bonding of the cement to the casing. However, this spacing is not satisfactory for determining data on or evaluating the relationship of the cement to the formation. Five-foot spacing between the transmitter and receiver is the best currently available for evaluating the relationship of the cement to the formation, but it is not accurate for determining bonding to the casing. Four-foot spacing is being used; however, it does not have satisfactory resolution for evaluating the relationship of the cement to either the casing or formation.

The significant fact remains that none of the tools located channels smaller than 30 degrees in the well. Such channels represent a significant avenue for movement of fluid and methods must be developed to locate these and even smaller channels. It is recommended that the logging industry continue research efforts toward increasing the sensitivity of the logging tools.

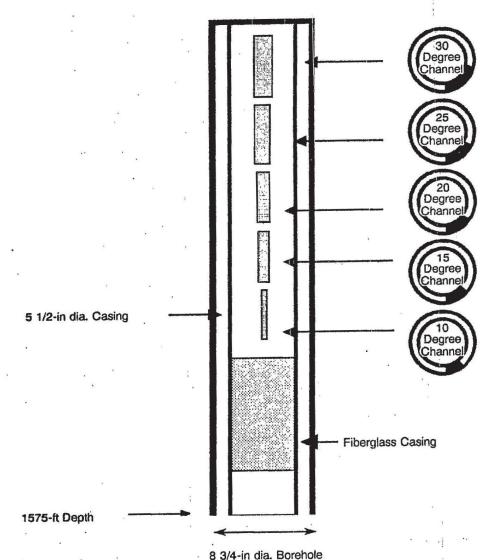
The research conducted on Logging Well No. 1 indicates that with the presently available tools, the ideal approach for evaluating the cement in an injection well is to run both the second generation tool and a calibrated cement bond tool with single transmitter/dual receiver







EPA - Injection Well Mechanical Integrity



iqure 7. Logging Well No. 2.

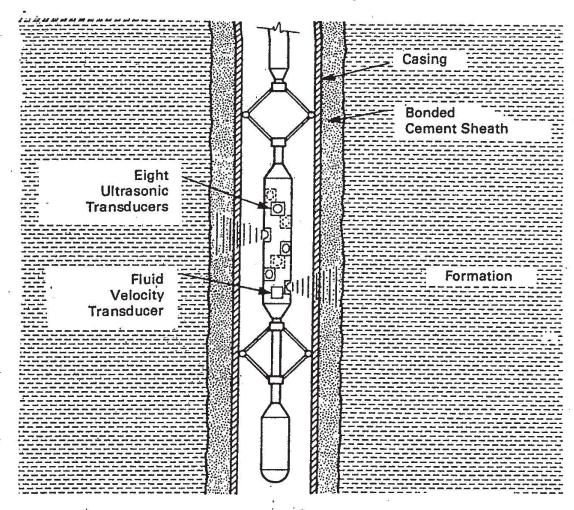
None of the logging tools presently commercially available located any of the 6 degree channels in Logging Well No. 1. The "second generation" tools located all of the 30, 60, and 90 degree channels and a calibrated "cement bond" tool with dual receiver 3-foot/5-foot spacing located all but one of the 30 degree and all of the 60 and 90 degree channels.

Results of tests in Logging Well No. 2 indicate that none of the presently available tools are capable of evaluating cement behind fiberglass pipe. Initial indications are that some prototype tools are able to identify 10 degree channels on the steel casing; however, this is based on preliminary data and much more testing must be done before definitive conclusions can be reached.





EPA - Injection Well Mechanical Integrity



The "second generation" tools generate a pulse of ultrasonic energy from each of the eight focused transducers that are arranged around the circumference of the tool. The strength and duration of the echoes reflected from the casing and cement are used to form an image of the cement distribution and quality around the casing. This information and the cement compressive strengths are two very useful pieces of data for evaluating the casing/cement bonding in a well.

Figure 4. Second generation tool.

SUPERIOR WELL SERVICES

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All interpretations are opinions based on inferences from electrical or other measurements and we cannot and do not guarantee the accuracy or correctness of any interpretation, and we shall not except in the case of gross or willful negligence on our part, be liable or responsible for any loss, costs, damages, or expenses incurred or sustained by anyone resulting from any interpretation made by any of our officers, agents or employees

February 8, 2010

RE: Cement Evaluation Log.

On February 2, 2010 Superior Well Services ran a Cement Evaluation Log using a Dual Receiver Bond Tool. This tool uses Sonic Wave Train to evaluate cement quality. The Bond Index is the percentage of pipe circumference bonded by cement and is classified as; Good Bond = 80%-100%, Fair Bond = 60% - 80%, and Poor Bond = 60% or less bond indicated. In my evaluation of the Bond Tool signal the Bond Index is as follows:

720' to 714' Fair Bond, 714' to 184' Good Bond, 184' to 181' Poor Bond, 181' to 152' Good Bond, 152' to 130' Fair Bond, 130' to 99' Good Bond, 99' to 91' Fair Bond, 91' to 76' Good Bond, 76' to 50' Fair Bond, 50' to 33' Poor to No Bond, 33' to 0' Fair Bond.

Cement Bond Log does not indicate any Fluid Channeling problems.

Sincerely,



TABLE 3C.10—CAPABILITIES AND GUIDELINES FOR RUNNING CEMENT-EVALUATION LOGS⁶³

	Conventional CBL	Radial Ultrasonic	Radial Pad
Amplitude/attenuation	Yes	Yes (different)	Yes
Travel time (transit time)	Yes	Yes (different)	Yes
Full waveform	Yes	No	Yes
Good bond identification	Yes	Yes	Yes
	(if shear arrival)		
Partial bond identification	Yes	Yes	Yes
Channel identification	No	Yes	Yes
Microannulus effect	Strongly affected	Moderately affected	Yes
	(repeat log under		
	pressure)		
Repeat (calibration) runs	Yes	Yes	Yes
Centralization	Essential	Less critical	Not a factor
	(Use attenuation-ratio log		
	where centralization is		
	difficult)		
Free-pipe calibration	Desirable	Not necessary	Not a factor
(above top of cement)			
Heavy mud	Moderately affected	Strongly affected	Not a factor
Gas in microannulus	Strongly affected	Strongly affected	Strongly affected
Casing geometry	No	Yes	No
Casing thickness	No	Yes	No
Casing corrosion	No	Yes	No

